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Performance Measurement and Improvement of Lean Manufacturing Operations: A Leanness Assessment Literature Review for the Product Development Industry

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Abstract. Today manufacturing sectors are more competitive than before. Thus, to execute an enterprise's transformation in a company emerging as a lean organization it is crucial to have assessments and performance measurements that observe multiple variables during the lean implementation patch. The objective of this paper is to demonstrate a research method focused on lean performance measurement assessments from previous works, summarizing and organizing the existing evaluation standards in a way to allow different industrial segments to replicate the screening steps for a literature review construction. As a result, the existing lean performance measurements and methods from the last 23 years were refined in order to highlight opportunities and insights for future researches to be developed on the lean field.

1. Introduction

A good manufacturing practice for production assembly can result in better productivity for the whole organization [1]. In order to improve the manufacturing processes of a firm, lean manufacturing (LM) is being adopted by enterprises since the early phases of a project; in a way to allow managers and team leaders to rapidly implement changes on product characteristics or requirements definition [2]. Lean manufacturing also relies on a series of tools and techniques focused on the manufacturing operations, including the product development (PD) industry. These are based on concepts from different applied sciences; likewise, a number of models are implemented for production process optimization to improve its characteristics or attributes from integral and differential calculus, accelerated approach methods, and others. Such applications are found in reordering inventory management points as well as in deterministic and stochastic operation researches, where uncertainties and risks are integrated into the estimates. In other words, lean manufacturing applies a wide variety of engineering and applied science techniques to support organizations on identifying the bottlenecks for the main processes [3]. Many authors have tried to describe the lean ever since it first appeared in the literature [4-11]. In common to all of them are waste elimination and the focus on available resource optimization [12]. According to Morgan and Liker, a lean company (LC) aims for lean practices along the whole lean development process (LDP), not only for the manufacturing shop phases [13,14] and working as a single-piece manufacturing flow [15]. Various methods for an enterprise's operational performance transformation are comprised under the lean strategy umbrella [16] and researchers have already demonstrated that implementing lean along a product development process (PDP), can support an enterprise to emerge as a lean organization and increase its overall operational results [17-21].



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2. Background

Each company's sector has expertise on its own development phases, that way when the process is in progress significant data can be collected [22]. Thus, the system solution shall be considered as a major input for the decision-making process by assessing every development phase, allowing companies and managers to react to changes with countermeasures [23] by attacking the leanness level performance results early in the project, supported by all stakeholders [24]. A leanness level is defined by Vinodh and Chintha [25] as a performance measure of lean operations. Comm and Mathaisel [26] and Bauch [27] also described leanness as a relative measure of whether a company is lean or not. The number of studies in the literature on leanness assessment is low compared to those on lean implementation areas [28] and according to Silvério et al. [29], there is also a lack of self-assessment methods for the leanness definition, associated with a roadmap to provide insights for decision makers.

3. Methodology

In order to provide insights for future researches on performance measurement and improvement of lean manufacturing operations, a literature review and results classification were performed according to the criteria presented in the work from Silvério et al. [29], where the collected data was synthesized and deployed as per the flowchart presented in the Figure 1. Same flowchart can also be replicated for different industrial segments, serving as a support tool for a literature review construction.

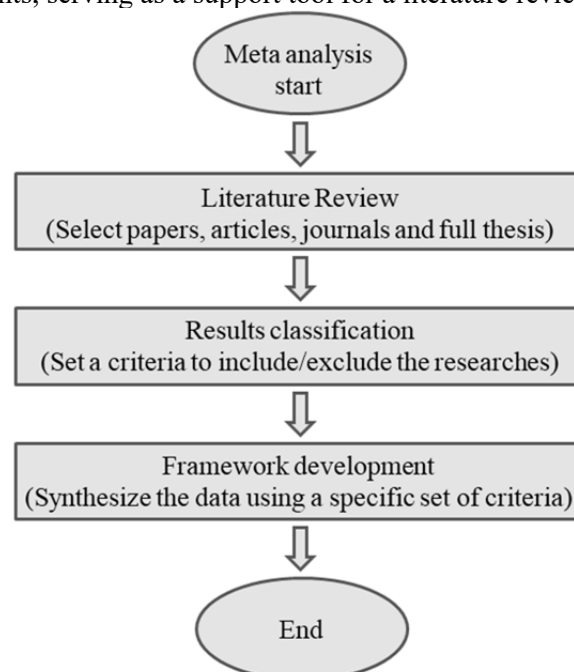


Figure 1. Research flowchart method (constructed by authors).

Similar to other literature review papers, the only restriction was that the reviewed articles were in English [30]. From the assessed studies, over 90 papers, articles, journals, and full thesis from the last 23 years were screened and refined in order to compose a systematic literature review and results classification according to the following criteria, presented in the Table 1 in a chronological sequence.

- A) Is the model approach a qualitative or quantitative assessment?
- B) Does the model have defined indicators?
- C) Does the model provide the enterprise's leanness level?
- D) Does the model provide a lean roadmap after the assessment is performed?

Table 1. Classification of literature sources framework. [29]

Author	A	B	C	D	Author	A	B	C	D
Karlsson and Åhlström	L	Y	N	N	Wong and Lai	T	Y	Y	N
Detty and Yingling	LT	Y	Y	Y	Kuhlang et al.	T	Y	Y	Y
Sánchez and Pérez	LT	Y	Y	N	Eroglu and Hofer	LT	Y	Y	N
Soriano-Meier and Forrester	T	N	Y	N	Chauhan and Singh	L	Y	Y	N
Nightingale and Mize	LT	Y	Y	Y	Vinodh and Vimal	L	Y	Y	Y
Goodson	LT	Y	Y	N	Nasab et al.	L	N	Y	N
Kumar and Thomas	LT	Y	Y	N	Azevedo et al.	L	Y	Y	N
Hon	LT	Y	Y	N	Anvari et al.	T	Y	Y	Y
Shah and Ward	LT	Y	N	N	Bhasin	L	Y	Y	N
Leung and Lee	L	Y	Y	N	Amin and Karim	T	Y	N	Y
Hobbs	LT	Y	N	Y	Karim and Arif-Uz-Zaman	T	Y	Y	Y
Kojima and Kaplinsky	LT	Y	Y	N	Gupta et al.	T	Y	Y	Y
Doolen and Hacker	LT	Y	Y	N	Alemi and Akram	T	Y	Y	N
Little and McKinna	LT	Y	Y	Y	Behrouzi and Wong	T	Y	Y	Y
Taj	LT	Y	Y	N	Mostafa et al.	LT	Y	Y	N
Wan and Chen	T	Y	Y	N	Wahab et al.	L	Y	Y	N
Ray et al.	T	Y	Y	N	Lemieux et al.	LT	Y	Y	Y
Wan	LT	Y	Y	N	Al-Najem et al.	LT	Y	Y	Y
Bonavia and Marin	LT	Y	Y	N	Al-Ashaab et al.	LT	Y	N	Y
Srinivasaraghavan and Allada	T	Y	Y	Y	Lucato et al.	LT	Y	Y	N
Wan et al.	T	Y	Y	Y	Elnadi and Shehab	LT	Y	Y	N
Shah and Ward	LT	Y	Y	N	Pakdil and Leonard	LT	Y	Y	Y
Matsui	LT	Y	N	N	Nesensohn et al.	L	Y	Y	N
Sanati and Seyedhoseini	T	Y	Y	N	Ramirez and Lorena	LT	Y	Y	Y
Dal Pont et al.	LT	Y	N	Y	Hosseini and Ebrahimi	L	Y	Y	Y
Barad and Dror	L	Y	N	Y	Mostafa et al.	LT	Y	N	Y
Bayou and de Korvin	LT	Y	Y	N	Soltan and Mostafa	LT	Y	Y	N
Bhasin	L	Y	Y	Y	Donovan	LT	Y	Y	N
Saurin and Ferreira	L	Y	Y	N	Urban	T	Y	Y	N
McLeod	LT	Y	N	N	Mahfouz and Arisha	LT	Y	Y	Y
Gurumurthy and Kodali	LT	Y	Y	Y	Vidyadhar et al.	LT	Y	Y	Y
Wu and Wee	L	Y	N	N	Omogbai and Salonitis	LT	Y	Y	Y
Marvel and Standridge	LT	Y	Y	Y	Maasouman and Demirli	LT	Y	Y	Y
Puvanasvaran et al.	L	Y	Y	N	Carvalho et al.	LT	Y	Y	N
Rahman et al.	LT	Y	N	N	Leite et al.	LT	Y	N	Y
Jeyaraman and Teo	L	Y	Y	Y	Hjalmarsson and Olsson	LT	Y	Y	Y
Singh et al.	LT	NA	Y	N	Abreu and Calado	LT	Y	Y	Y
Zanjirchi et al.	LT	NA	Y	N	Rajpurohit et al.	LT	Y	Y	Y
Sun	LT	NA	Y	N	Galankashi and Helmi	LT	Y	Y	N
Nordin et al.	L	Y	Y	N	Gonçalves and Salonitis	LT	Y	N	N
Anvari et al.	L	Y	N	Y	Sangwa and Sangwan	LT	Y	Y	N
Asadi and Panahi	T	Y	Y	N	Albzeirat et al.	LT	Y	Y	N
Aurelio et al.	LT	Y	Y	Y	Bento and Tontini	LT	Y	Y	N
Anvari et al.	LT	Y	N	Y	Rakhmanhuda and Karningsih	LT	Y	Y	Y
Bhasin	LT	Y	Y	N	Belhadi et al.	LT	Y	Y	N
Seyedhoseini et al.	L	Y	Y	N	Pakdil et al.	L	Y	Y	Y
Vinodh and Chintha	LT	Y	Y	Y	Aikhuele and Turan	LT	Y	Y	N
Vinodh and Balaji	LT	Y	Y	Y	Silvério et al.	L	Y	Y	Y

Y=Yes; N=No; NA=Not Applicable; L=Qualitative; T=Quantitative; LT=Qualitative and Quantitative.

4. Results and analysis

Karlsson and Ahström [31] presented the first lean assessment model found in the literature in 1996. It consisted of a checklist to determine if a company is adopting lean aspects on its lean journey or not through a set of nine measurable determinants on waste elimination. The model had the purpose of evaluating the manufacturing progress of an enterprise focusing on lean production implementation, and it is based on the lean core principles described in the book “The Machine that Changed the World” by Womack, Jones, and Roos [19], where the term LM was coined by Womack after his visit to Japan, to witness the effectiveness of the Toyota Production System (TPS) [32]. Although the first leanness research was published in 1996, the next leanness study appeared in the literature only four years later in 2000, and was by Detty and Yingling [33]. The authors published a case study focused on quantifying the lean conversion benefits in a manufacturing enterprise. The framework provided recommendations for an existing manufacturing enterprise to become lean based on a discrete event simulation tool supporting managers’ decisions on implementing leanness or not. The operational benefits quantification of each lean principle was considered by the method.

From 1996 on, multiple leanness assessment methods, frameworks and LM concepts were published by different authors over the years; including the work from Silvério et al. [29] that was used as results classification and criteria to include/exclude the researches for the literature review analysis and conclusions presented by this study.

As a result, this paper compiled various performance measurement and improvement of LM operations in the PD industry. A bibliographic research was conducted to better organize the research problem [34] and the proposed framework from Silvério et al. [29] was used as results classification and criteria to include/exclude the researches for the literature, dividing the selected papers into four categories: qualitative or quantitative assessment model, indicators defined or not, leanness level defined or not and lean roadmap provided or not. As a result, there were (21) qualitative, (16) quantitative and (59) qualitative/quantitative researches among the literature sources. In addition, (91) papers defined indicators and (2) not. For the leanness level definition, (80) researches proposed a leanness level classification and (16) not. Regarding the roadmap being provided after the assessment performed, (42) papers presented a roadmap and (54) not. Thus, from the screened researches it was identified a reduced number of papers focused on lean implementation roadmaps; and a widely range of practical studies on LM implementation practices. In order to reinforce an unifying view of the leanness and roadmap practices concept, we propose the following definition of leanness: ‘Leanness is an overall progress measurement of the lean production in a firm, focused to determinate where the assessed enterprise successfully applies the lean initiatives and where the lean implementation practices must be incorporated or improved, substantiated by successful application cases and models.’

5. Conclusions

As a conclusion, leanness methods are in a wide range, varying from qualitative/quantitative checklists to multiple complex numerical models. Furthermore, the leanness research field varies and continues to be analyzed in order to possibly compose a standardized process for enterprises emerging as true lean organizations. Thus, the analytical hierarchy process (AHP) can also serve as a reference methodology for future studies to be developed on the leanness performance measurement and improvement of LM operations, as far as by applying AHP in the selected determinants the fundamental aspects could be accurately analyzed in a multi-factor manner [35]. This paper will also serve as insights for future researches and practitioners focused on the new performance measures, tools and methods for the lean operations; and as a practical guidance do be considered by managers and decision makers when selecting a leanness framework to be deployed on their organizations. Moreover, this paper will serve as a screening reference method for conducting a literature review in different industrial segments, as far as it demonstrated to be a useful support tool to organize the existing evaluation standards in a way to allow different industrial segments to replicate the screening steps for a literature review construction, as demonstrated by Figure 1 research flowchart method and Table 1 classification of literature sources framework.

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